ULTRA-SENSITIVE SENSOR BASED ON WHISPERING GALLERY MODE MICRO-RESONATORS

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Microsphere -- a low-loss photon trap, novel optical (micro)cavity

Whispering-gallery modes - closed circular waves under total internal reflection

(Term by J.W.S.Rayleigh, analogy to acoustic modes in the gallery of St Paul cathedral)

Sustained in any axisymmetric dielectric body with $R \geq \lambda$

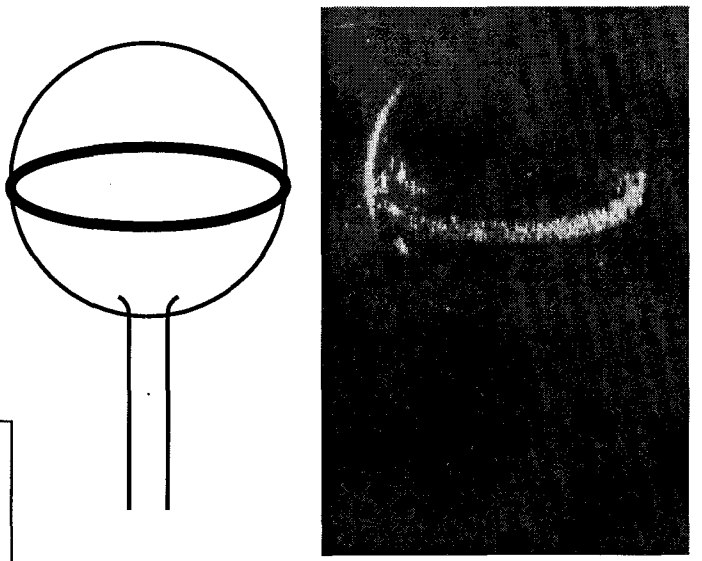
low material loss (transparent material, e.g fiber grade silica)

low bending loss ($R >> \lambda$)

low scattering loss (TIR always under grazing incidence

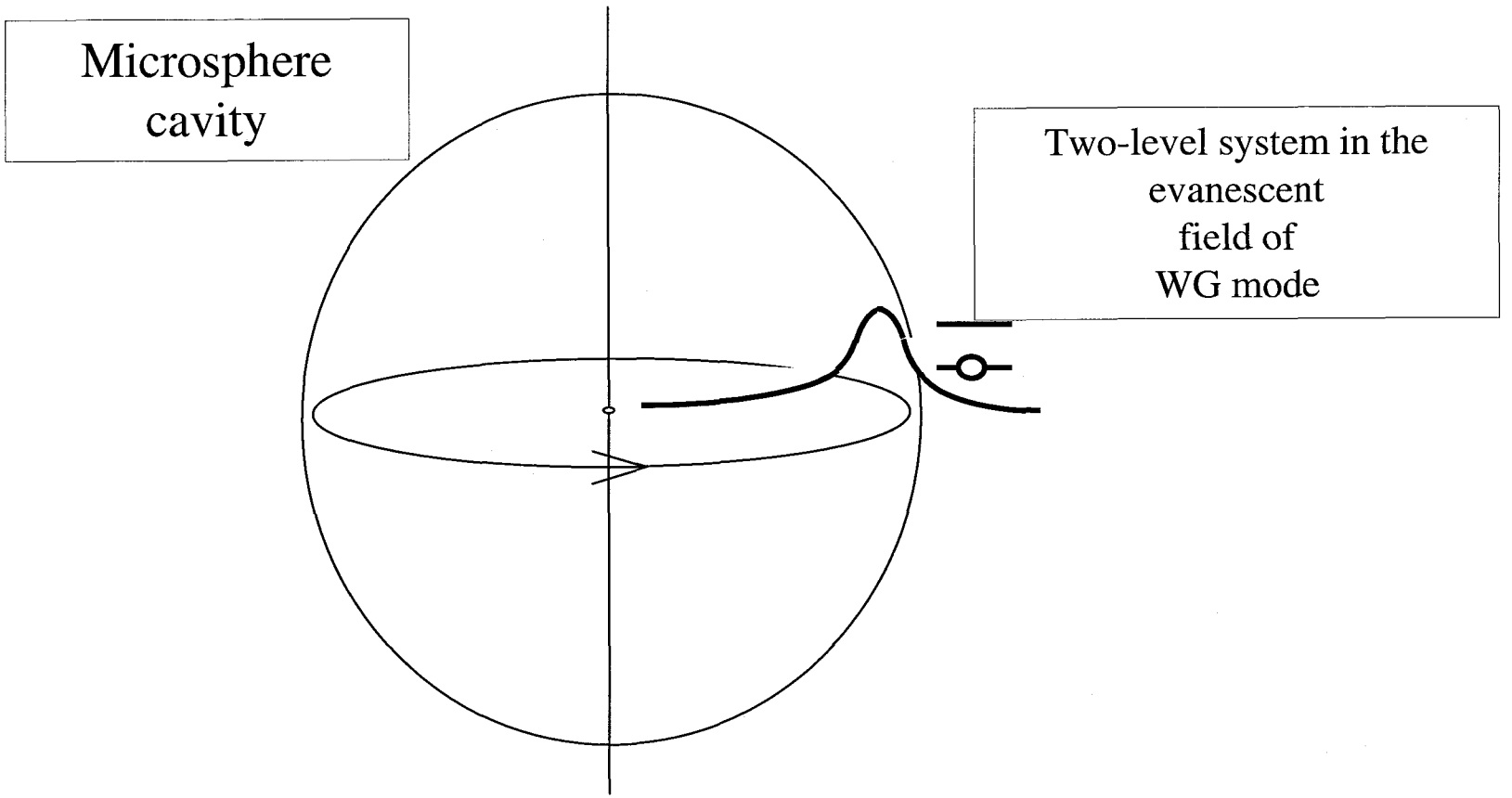
+ molecular-size surface roughness)

Quality-factor $Q = \lambda/\Delta\lambda_{RES}$	-	up to $\sim 10^{10}$
Photon lifetime $\tau = \lambda Q/2\pi c$	-	up to $\sim 3\mu s$
(cavity ringdown time)		
visible and near-infrared band:	*Opt.Lett. 21, p.453 (1996)*	
	Opt.Lett. 23, p.247 (1998)	



Visualization of WG mode field by residual scattering in silica microsphere, *V.S.Ilchenko et al, Opt.Commun. 113, p.133(1994)*

Microsphere cavity modes sense external medium through evanescent wave

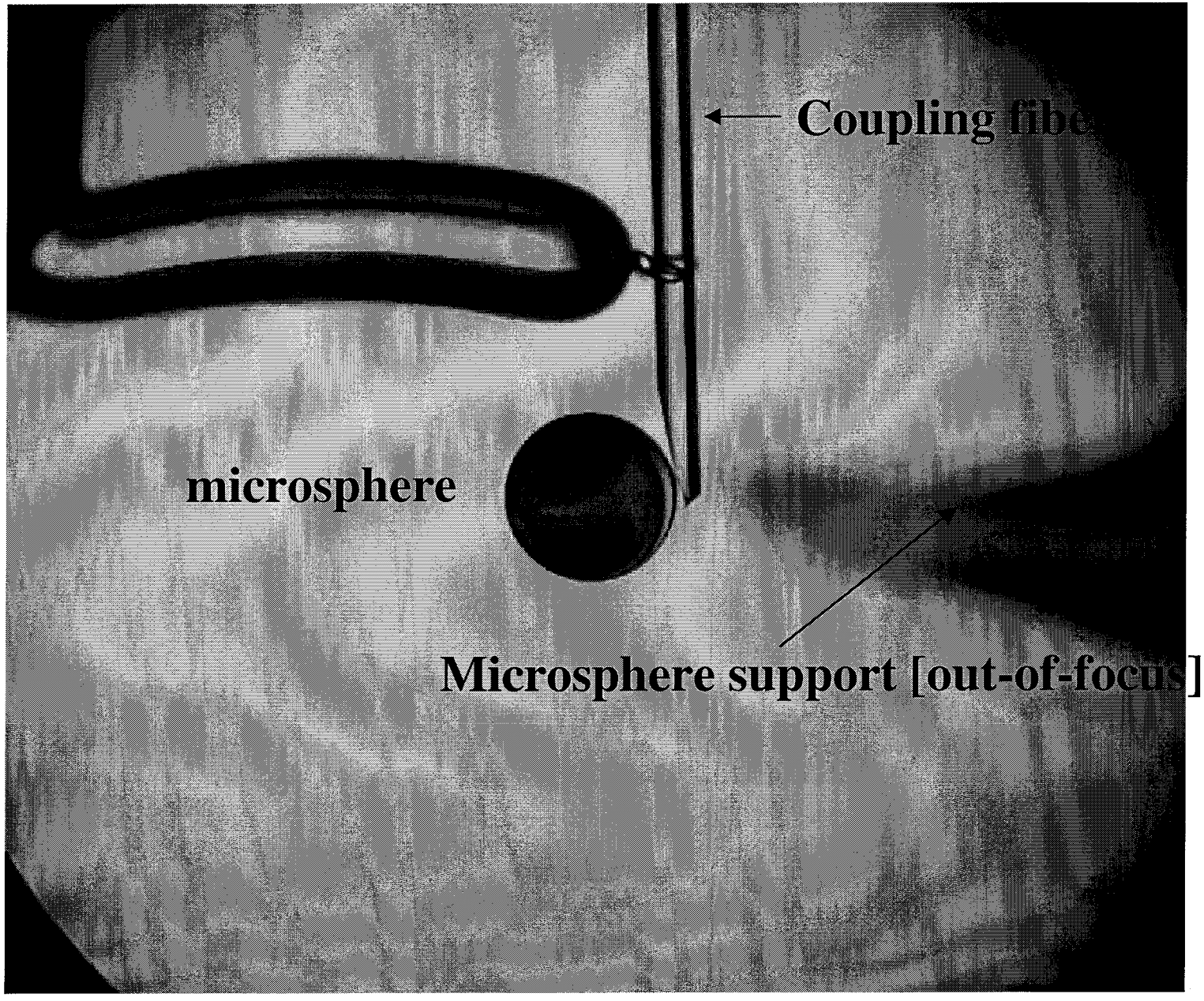


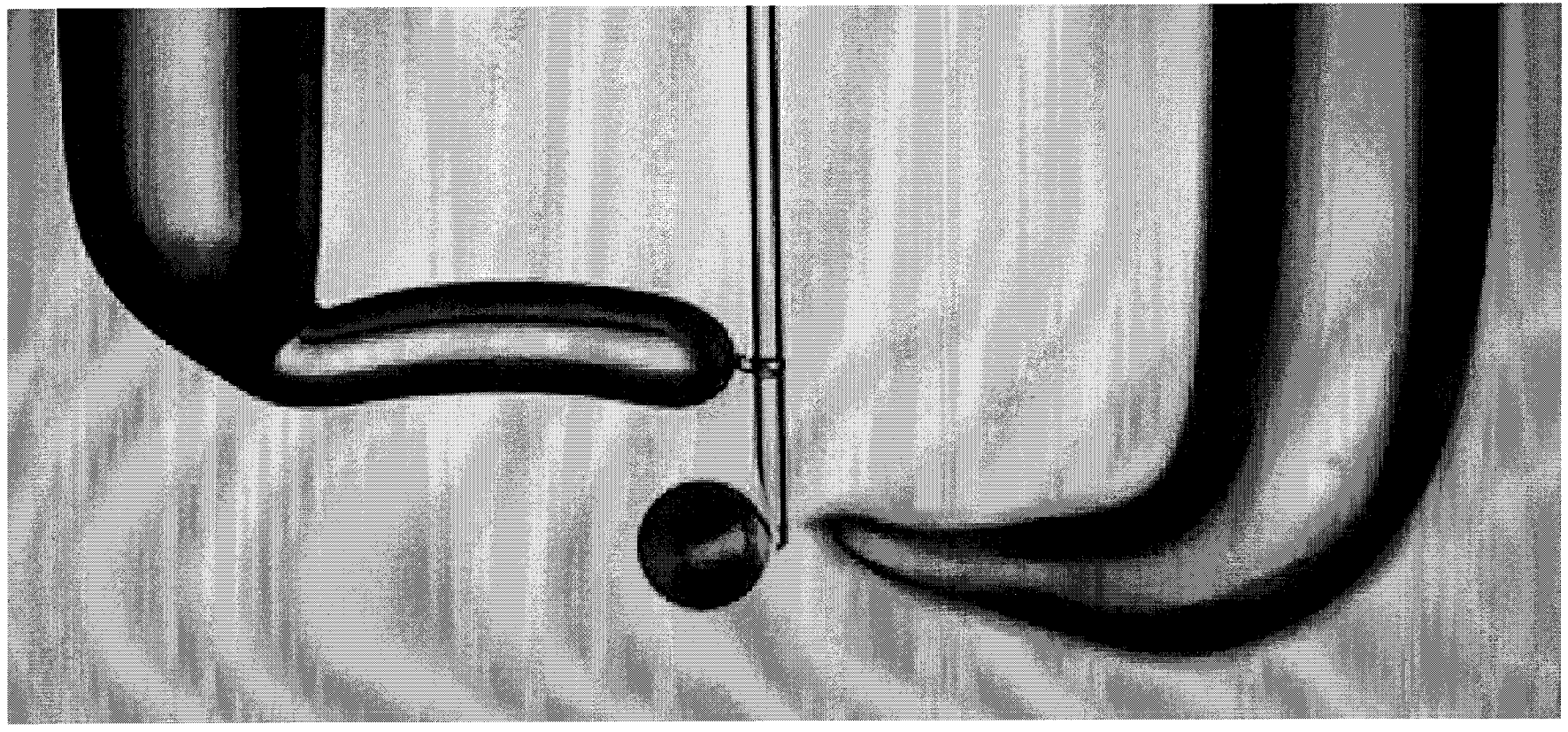
Microspheres as sensors

Since evanescent wave samples immersion medium, losses will affect measured cavity Q

Sensitivity can be enhanced by using absorption features to increase losses and further reduce Q

As with immunoassays, use a fluorophore to indicate presence of analyte


Coupling fibe
microsphere
Microsphere support [out-of-focus]



A microsphere supported at the end of the glass rod on the right and optically coupled to the center fiber

Measurement Technique

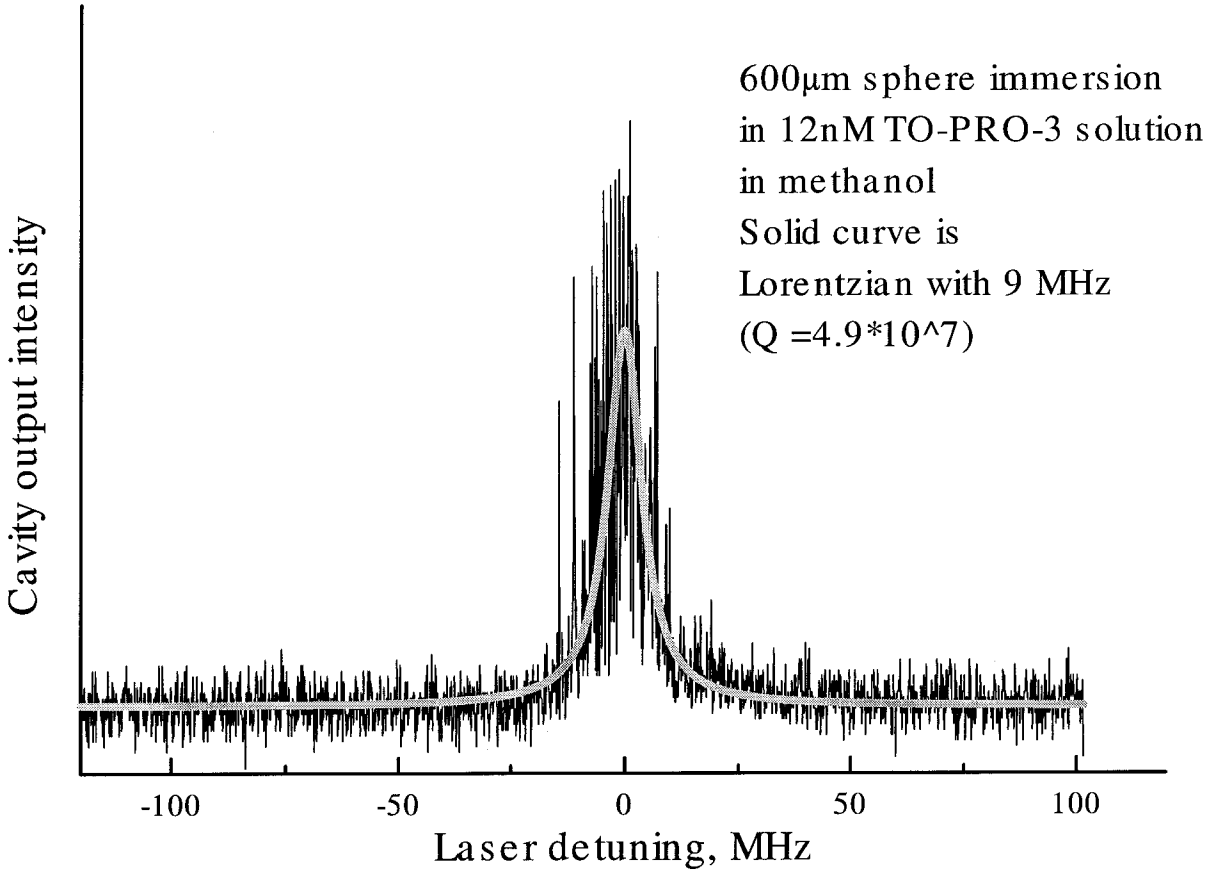
$Q<10^8$

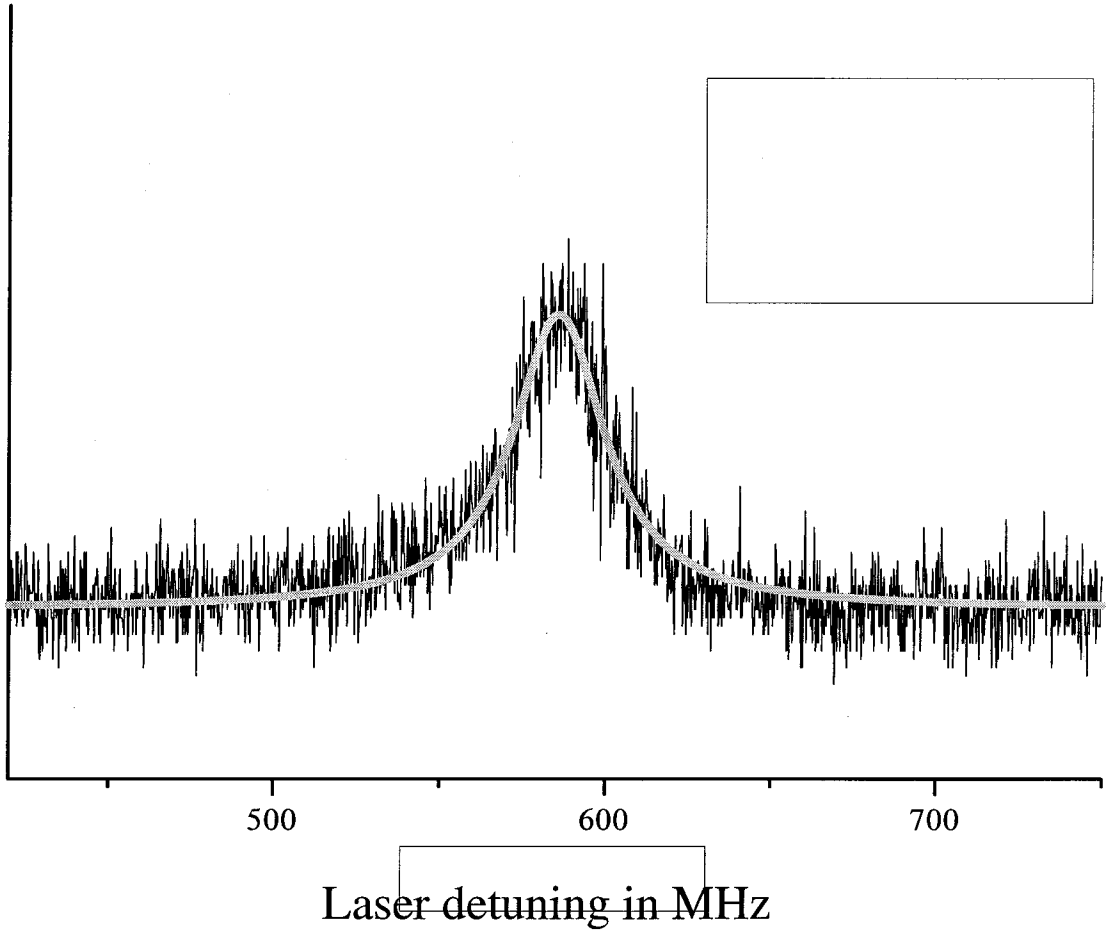
Since cavity bandwidth is larger than laser linewidth, we can scan the laser frequency and measure the Q directly

$Q>10^8$

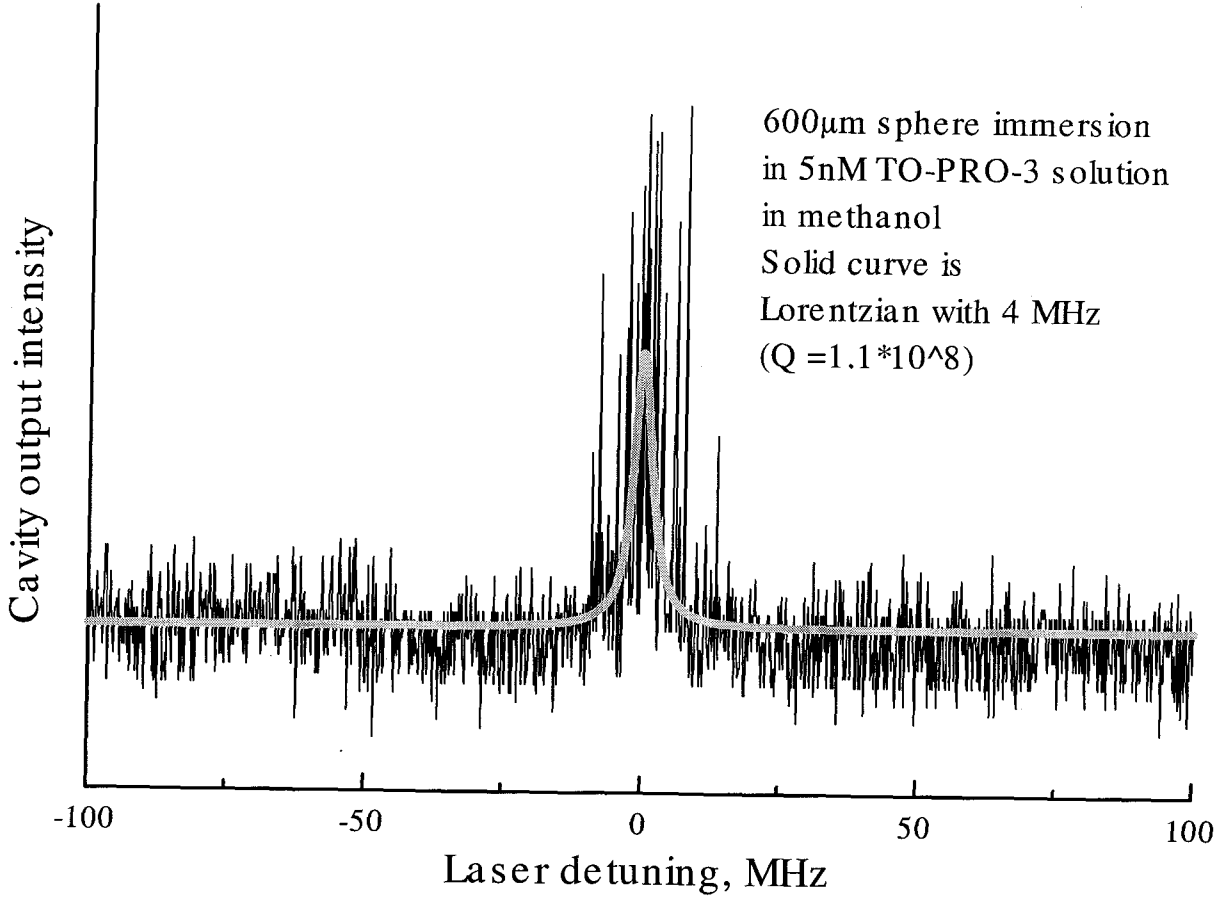
Use cavity ringdown to measure Q

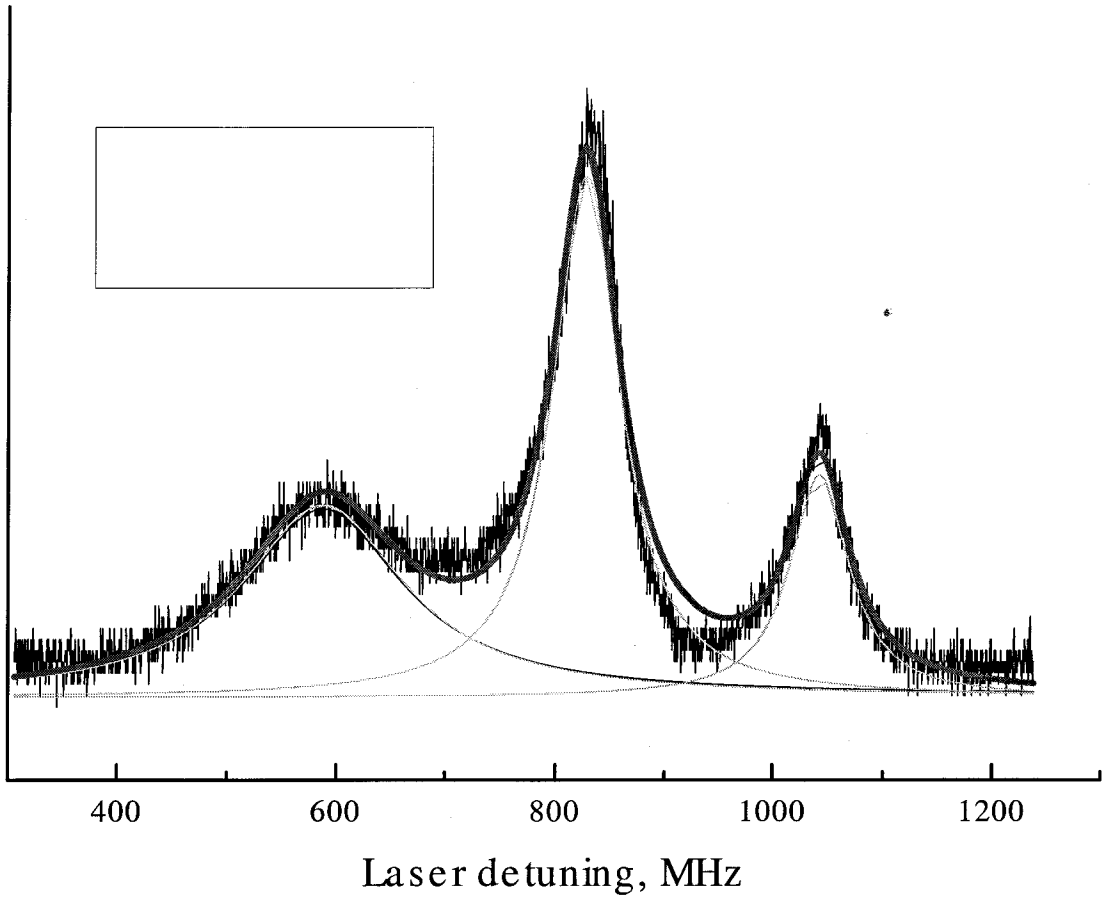
Direct measurement of μsphere Q



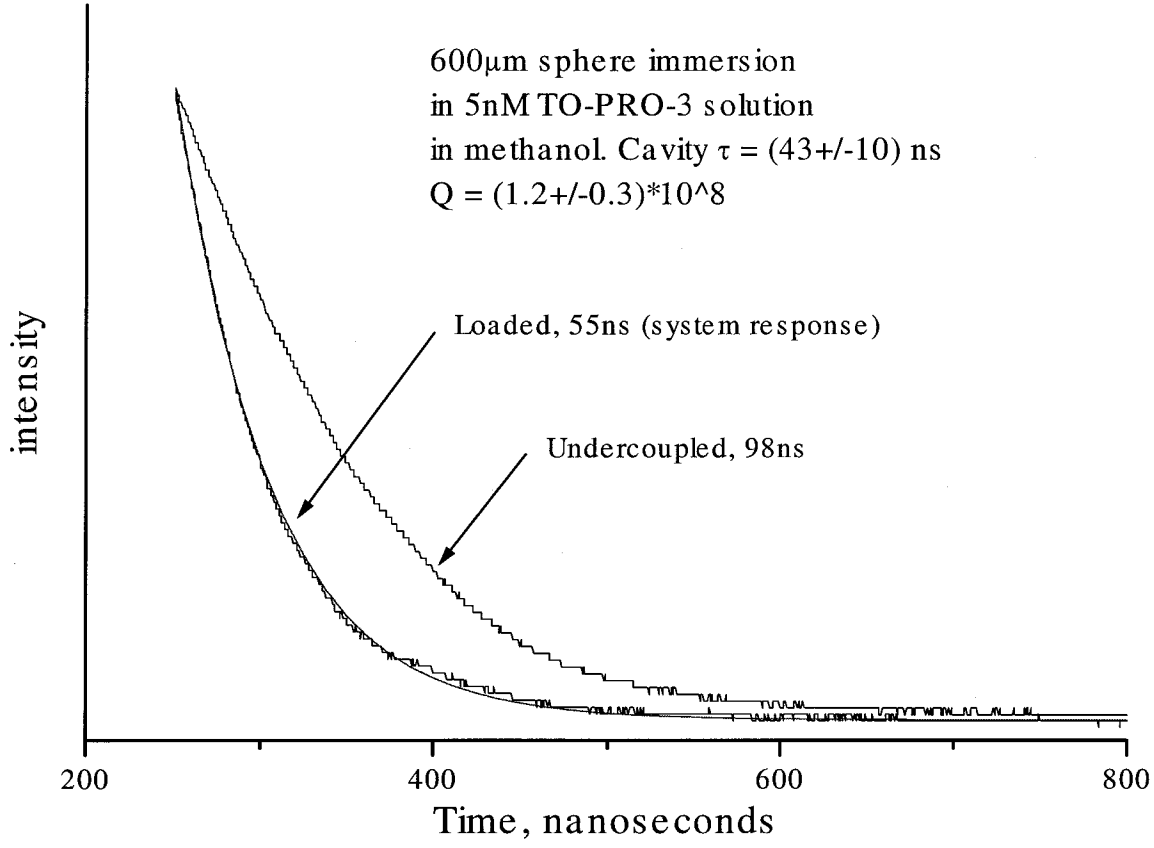


600 μm sphere in 150 nM solution of TO-PRO-3 in Methanol Δ=34 MHz

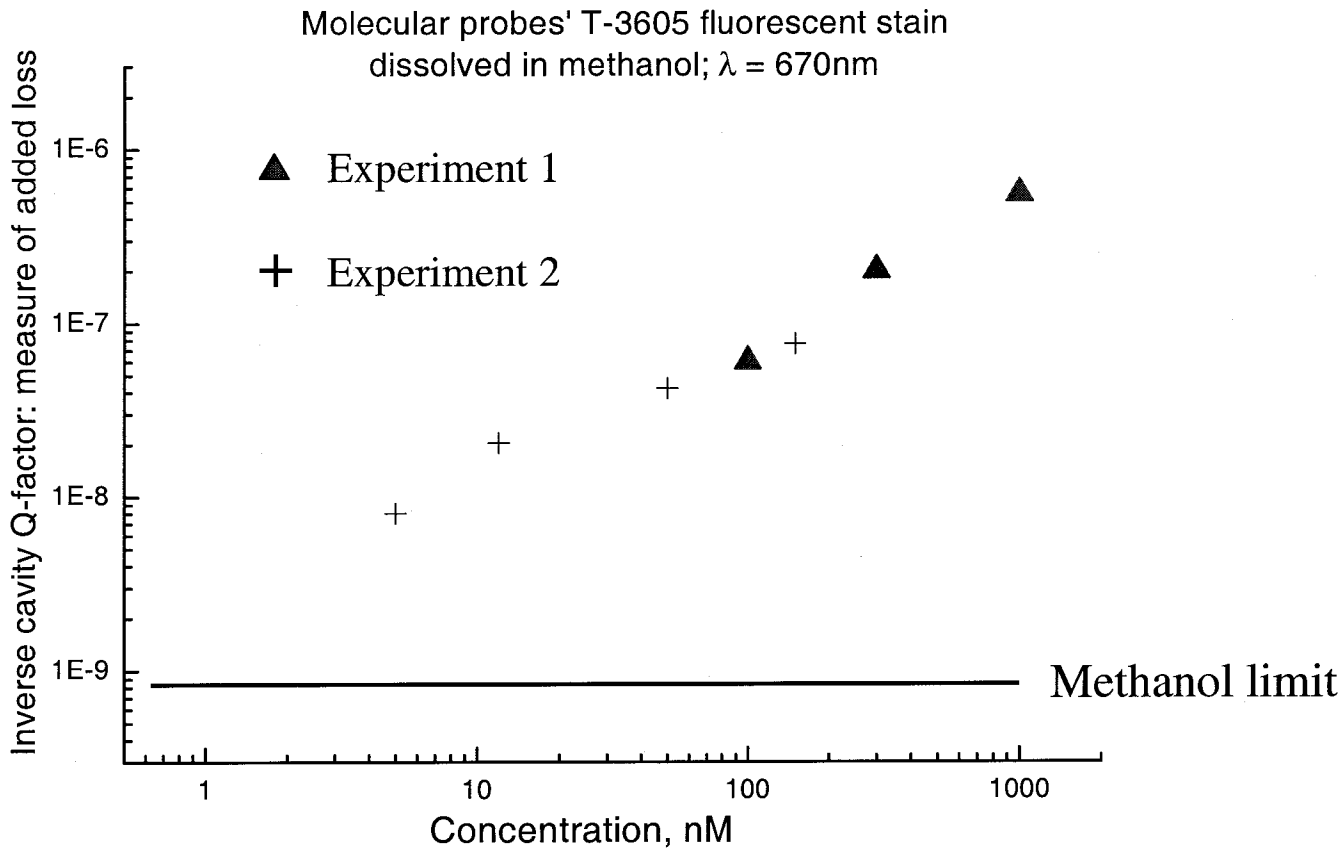

600μm sphere immersion
in 5nM TO-PRO-3 solution
in methanol
Solid curve is
Lorentzian with 4 MHz
(Q =1.1*10^8)
Cavity output intensity
-100
-50
0
50
100
Laser detuning, MHz



600 μm sphere in 500 nM solution of TO-PRO-3 in Methanol. Δ=58 MHz. Note the presence of other cavity modes that show up as the detuning range is ~ 1GHz



Cavity ringdown measurement of microsphere cavity Q.
$Q=1.2*10^8$ vs $1.1*10^8$ from linewidth measurement



Measured concentrations of analyte with microsphere sensor